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NOTE ON THE VERTICAL DISTRIBUTION OF MALLOMONAS.

G. C. WHIPPLE AND HORATIO N. PARKER.

MALLOMONAS is a microscopic organism that is often found in the water of ponds and lakes. It usually occurs in greatest abundance in the spring and autumn, but occasionally it appears at other seasons. It is an odor-producing organism, and as such is liable to give trouble in water supplies. Its odor is similar to that of Cryptomonas, which has been described as resembling "candied violets." As the odor increases in intensity it loses its aromatic qualities and becomes "fishy." In addition to its odor it has a slight sweetish taste. Mallomonas is not known to have ever given serious trouble in a water supply, because it is seldom found in large numbers for any considerable length of time, but several cases are on record where it has been present in water supplies, and where it has undoubtedly caused a noticeable odor. Observations seem to indicate that whenever it is present in the water to the extent of about 500 per cc. its odor may be recognized. However, this paper is not concerned with the odor-producing properties of Mallomonas, nor its effect on water supplies, so much as with the organism itself, its structure, its development, and especially its peculiar, characteristic, vertical distribution in ponds and lakes.

The earliest description of Mallomonas was that of Perty in 1852. To him we owe its generic and specific names. Some writers have questioned the claim of Mallomonas to rank as an independent genus. Stein held that it was but a monad of Synura, freed from its colony. Recent observations have established the position advanced by Perty and adopted by Kent.

Kent's description of Mallomonas is as follows:

GENUS MALLOMONAS PERTY.

Animalcules free-swimming, oval or elliptic, persistent in shape; cuticular surface indurated, clothed with long, non-vibratile, hair-like setæ; a single, long, vibratile flagellum produced from the anterior extremity; contractile vesicle indistinctly developed. Inhabiting fresh water.

M. PLOSSLII PERTY.

Body ovate or elliptical, slightly narrower anteriorly, cuticular surface finely shagreened or crenulate, thickly clothed with fine hair-like setæ, whose length is less than that of the body; flagellum long and slender, retractile; endoplasm vacuolar, amber color or greenish-yellow; contractile vesicle indistinct, posteriorly located. Length of body, 1-1000″ to 1-900″. Habitat marsh water.

This description is somewhat incomplete and does not take into account certain common variations from the type form. Examination of a large number of specimens found in the waters of Massachusetts and New York has revealed the following facts:

The length of Mallomonas varies at different times and in different localities from 20 to 60 μ. The ratio of length to width varies from 4 to 1. Sometimes the bodies are long and narrow, and sometimes they are almost spherical, resembling the Rhizopod, Actinophrys. The older forms are somewhat more spherical than the younger ones. All forms of Mallomonas are more or less spherical in end view.

The setæ or spines vary in length from 15 μ to 30 μ; the average length is about 25 μ. They have a diameter of 0.3 μ at the base and taper to a point at the fore end. They are generally straight, but, being flexible, they sometimes appear to be curved. At the base they bend sharply like a polo stick and are attached to basal plates which have a rectangular shape. It is the irregular lapping of these basal plates that produces the corrugated appearance of the cuticular surface mentioned in Kent's description. The setæ are easily broken off, and it is not uncommon to see specimens with only two or three setæ present. When the organism moves forward the setæ are directed backwards.

The color of the organism is usually green when the specimen is young and fresh, but sometimes it changes to greenish-yellow or brown. Besides the two chromatophores, a contractile vacuole and numerous oil globules may be discerned. The nucleus, if present, is indistinct. At times a globular, balloon-like body is attached to the posterior extremity. It is apparently a development of the contractile vacuole. It is usually small and colorless, with a granular structure, but sometimes it is large, green, and spore-like. This body may be connected with some process of reproduction. Reproduction of Mallomonas takes place by sporular encystment. The protoplasm contracts, assumes a spherical shape, shrinks, and becomes invested with a thin integument. A single spore is formed by each individual. The liberated spores have a brown color and are occasionally surrounded by a gelatinous tegument.

All the forms of Mallomonas observed by the writers, notwithstanding their variations in size and shape, may be properly included under the single species *M. plosslii* Perty.

Fresenius (*Infusionsthiere,* Abth. III, 1878) described a minute form, to which the name *M. fresenii* has been given. Zacharias (*Forschungsberichte,* Theil I, s. 16) has described a species which he calls *M. acaroides* Zach. It differs from the type form only in having the setæ thicker and more curved than those of *M. plosslii* (*Vergl. zur Kenntniss kleinsten Lebensformen,* 1852, s. 83). He has also described (*Forschungsberichte,* Theil I, s. 73) a new variety which he has called *M. acaroides* Zach. var. *producta* (Seligo). It differs from the previous form by its larger size and by its longer spines. Seligo (*Ueber einige Flagellaten des Süsswasserplankton,* Jan. 3, 1893), under the name Lepidoton, has described the same form.

Mallomonas is of interest to students of aquatic life because of its peculiar vertical distribution during the summer. Three instances of this are on record; namely, in Lake Cochituate and Whitehall Pond, of the Boston supply, and in Ridgewood Reservoir, of Brooklyn, N. Y.

Lake Cochituate is a lake of almost colorless water, with a maximum depth of sixty feet and with well-marked stagnation periods. Mallomonas is often found there in numbers varying from 50 to 100 per cc. On June 24, 1896, it suddenly appeared in the lower strata of water near the gate house. There were 116 per cc. at the mid-depth thirty feet, 42 per cc. at the bottom sixty feet, but none at all at the surface. The following week the same peculiar distribution was observed, the surface water being free from them, while the number at the mid-depth was 336 per cc. This arrangement continued until the first of September. During all this time not a single individual was observed at the surface, and the numbers at the mid-depth fluctuated between wide limits, on one day being as high as 3640 per cc. At the bottom they were invariably present, but always in much smaller numbers than at the mid-depth. The following table gives the number of Mallomonas at the surface, mid-depth, and bottom for the entire period of growth.

	Number per cc.		
Date.	*Sur.*	*Mid.*	*Bot.*
June 18,	0	0	0
24,	0	116	42
July 1,	0	336	2
8,	0	46	
15,	0	724	276
22,	0	1102	158
July 28,	0	264	162
Aug. 4,	0	3640	6
11,	0	1200	10
18,	0	1380	4
25,	0	298	8
Sept. 1,	0	0	0

On July 17 a series of samples was taken at intervals of ten feet through the vertical, and the following results were obtained.

Depth.	Mallomonas per cc.
Surface.	0
10 ft.	0
15 ft.	2
20 ft.	1454
25 ft.	794
30 ft.	548
40 ft.	112
50 ft.	88
60 ft.	64

These figures, together with the temperature of the water at various depths, are shown by the diagram. It will be observed that the greatest numbers were found just below what may be called the thermocline. From the surface down to a depth of ten feet the temperature of the water was uniform. Between ten and twenty feet the temperature fell rapidly. The water in this stratum was not stagnant, however, as other observations — not given here — indicated. But below a depth of twenty feet the temperature was practically constant from week to week, indicating a condition of stagnation. It was at the boundary line between the stagnant water and the slowly circulating water above it that the Mallomonas reached their greatest growths. Below this depth the numbers decreased rapidly.

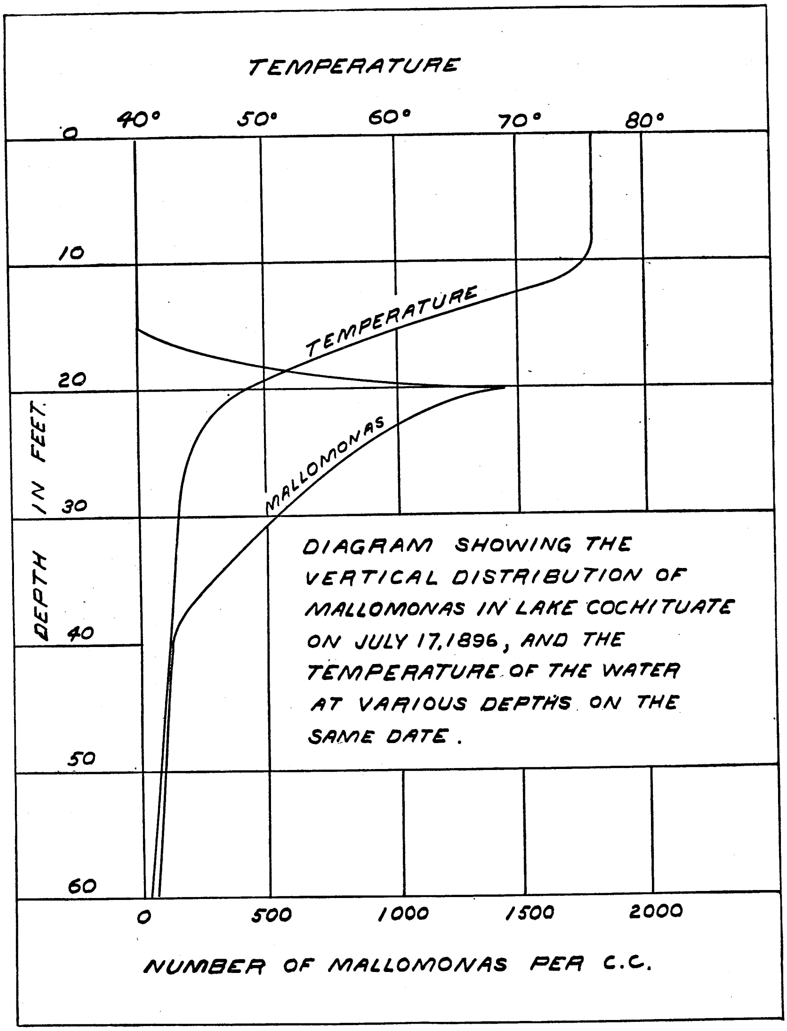

DIAGRAM SHOWING THE VERTICAL DISTRIBUTION OF MALLOMONAS IN LAKE COCHITUATE ON JULY 17, 1896, AND THE TEMPERATURE OF THE WATER AT VARIOUS DEPTHS ON THE SAME DATE.

A similar case of vertical distribution occurred in Whitehall Pond during the summer of 1897. This is a pond of dark brown water, with a depth of about twenty-five feet. From May 7 to June 7 the surface samples contained a few Mallomonas. On June 14 there were 110 per cc., after which there were less than 11 per cc., until August 23 they suddenly rose to 2186 per cc. This suggested that there had been a growth at the top of the stagnation layer as in Lake Cochituate, and that a high wind had stirred the water and brought the organisms to the surface. This seemed the more probable, because the color of the surface water, which had been 0.57, rose to 0.66. On August 27, four days later, samples were taken every five feet from surface to bottom. The following results were obtained.

Depth.	Number of Mallomonas per cc.	Color.
1 ft.	20	0.54
5 ft.	880	0.54
10 ft.	1936	0.57
15 ft.	84	0.64
20 ft.	40	1.06

These observations seemed to show that there had been a large growth below the thermocline, that the organisms had been scattered through the water, and that they were now sinking back toward their original position. The color readings showed that the pond had been stirred to a depth of only about fifteen feet.

On September 14 the vertical distribution was as follows.

Depth.	Number of Mallomonas per cc.
1 ft.	0
5 ft.	0
15 ft.	10
20 ft.	432
25 ft.	472

In November, during the period of autumnal circulation, Mallomonas again appeared at the surface, the number per cc. reaching forty.

This tendency of Mallomonas to concentrate just below the thermocline was observed in Ridgewood Reservoir, Brooklyn, N. Y. In July, 1898, on the 6th inst., the water at the surface contained 60 per cc., while at the bottom (twenty feet) there were 156 per cc. At a depth of fifteen feet they were more numerous, but the actual number per cc. was not determined. On July 14, after a high wind, the surface water contained 420 per cc.

The reasons for the peculiar vertical distribution of Mallomonas are not wholly apparent, but the reactions of the organism to light and temperature offer some suggestions.

Mallomonas possesses a strong heliotropism. This has been shown by laboratory experiment. A brass tube having glass ends was filled with water containing 3360 Mallomonas per cc., and so placed that one end was exposed to the light, while the other was covered by a black cap. After standing for forty-eight hours in a horizontal position, portions of the water were carefully withdrawn simultaneously from each end of the tube and examined. At the dark end of the tube only 810 Mallomonas per cc. were found, but at the light end there were 9480 per cc.

From this tendency to move towards the light, it would appear that the Mallomonas had tried to get as near as possible to the surface where the light was strongest, but that the warm, agitated water above the thermocline did not offer favorable conditions for growth. During the winter Mallomonas does rise to the surface, and is usually more abundant there than elsewhere in the vertical.

Apparently Mallomonas prefers to live where the light is strong, where the temperature is low, and where the water is quiet. No doubt the long setæ (and possibly the balloon-like bodies referred to above) help to keep the organisms from sinking in quiet water. These become broken off when the water is violently agitated, and after that the organisms sink more readily. This may partially explain why Mallomonas does not develop near the surface during the summer.